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Developing and Evaluating a Hot Water-Assisted Extractor for Making Instant Drink from Date Kernels Powder

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ABSTRACT

Date tree (*Phoenix dactylifera* L.) is one of the oldest cultivated trees in the world, which grows in tropical and subtropical regions. This product is one of the most important products of the Middle East and North Africa. In this research, date kernel extract (DKE) was produced from date kernel powder in a hygienic and mechanized process. Hot water-assisted extraction of compounds from date kernel powder was carried out in the chamber system made in the research. The experiments were conducted using the response surface method (RSM)-central composite design. Independent variables included temperature and time of processing and liquid-to-solid ratio. The obtained solutions were dried by a vacuum rotary evaporator and some quality characteristics (total soluble solids (TSS), antioxidant activity, total phenolic content (TPC), melanoidins, and sensory properties) were evaluated. The results showed that the triple factors of temperature, time and liquid-to-solid ratio have a direct effect on the extraction efficiency, so that the increase of these factors had a significant effect on the extraction efficiency. The predicted efficiency equations for each of the above cases were significant at the 5% level and R^2 was above 0.95. The results of the TSS, TPC, melanoidins and sensory attributes confirmed the high desirability of the produced DKE.

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INTRODUCTION

Date kernels comprise ~9% of the total weight of date fruit, which varies according to the variety, place of cultivation, harvest season and storage method (Al-Farsi & Lee, 2008). Studies have shown that date kernels have antioxidant, antimicrobial, antiviral and anticancer properties. It has been found that date kernel is a suitable source for fiber extraction and can be used in food industries (Al-Farsi et al., 2007). The high consumption of fiber in date kernels reduces blood pressure and improves insulin levels in diabetic patients (Marina et al., 2009; Al-Qarawi et al., 2005). The use of date kernel ash is also recommended as a low-cost absorbent to remove phenolic compounds. Ash can be a good substitute for activated carbon (Hossain et al., 2014; Danish et al., 2014). There are many similarities between date kernel extract (DKE) and instant coffee; therefore, the terms of "instant tea" or "instant coffee" can be used for thesis products (Eira et al., 2006). Coffee is one of the most consumed beverages in the world and the second traded commodity after petroleum (Mussatto et al., 2011). Instant coffee is a coffee product that has attracted the attention of consumers due to its quick and easy preparation as well as the very good aroma and taste (Capek et al., 2014). Instant coffee is produced after washing and grinding. Soluble solids and volatile compounds that contain flavor are extracted from coffee beans using water. In this step, water at high temperature and under pressure (to keep the water in a liquid state) is used to extract all the soluble substances from the coffee beans. For drying, the methods of freezing drying and spray drying are often used in instant coffee production (Mussatto et al., 2011).

The extraction process, which is achieved by the removal of liquid and solid materials from the powder, is often made possible by using common techniques based on the extraction ability of different solvents and the application of heat or mixing. The most common process to obtain bioactive compounds from plants is solvent extraction and steam distillation (Belščak-Cvitanović & Draženka, 2017). Extraction is done in two traditional and new ways (Azmir et al., 2013). The most important factor in extraction is choosing the suitable solvent. In selecting solvents for extracting bioactive compounds, the amount and ratio of solvent and solute, mass transfer rate, safety, environmental issues and economic feasibility should be considered (Azmir et al., 2013). In the past, various extraction techniques were proposed, which are known as traditional extraction techniques (Mustafa & Turner, 2011). In most of these methods, the liquid solvent is poured on the solid sample at atmospheric pressure, and the extraction is done by penetrating the solvent into the structure of the solid sample and dissolving the desired compound. Extraction with these methods requires a long time and a large amount of samples. Also, in these methods, large amounts of organic solvents are needed, which have a high cost and ultimately leave negative environmental and economic effects. Another drawback of traditional extraction methods is that the final extracts often require a lot of concentration and purification before chemical analysis (Mustafa & Turner, 2011, Ramos et al., 2002).

Today, many new and different methods have been introduced to extract functional compounds from plant sources. Some of these extraction methods are: supercritical fluid extraction (SFE), pressurized liquid extraction (PLE) and pressurized hot water extraction (SWE) (Herrero et al., 2013). In the supercritical fluid extraction (SFE) method, extraction is performed using a fluid that is in a supercritical state due to its high temperature and pressure. Supercritical fluid extraction is the most effective and efficient way to extract medicinal plants (Sapkale et al., 2010). In supercritical fluids, pressure and temperature affect the separation efficiency, so that these two factors are directly related to the solubility of the sample (Herrero et al., 2013). The overall extraction may be divided into three steps: The removal of the desired compound from the solid substrate, the diffusion of the compound into the solvent that has penetrated into the solid substrate, and the transfer of the solute to the rest of the extracting solvent (Mussatto et al., 2011). One of the valuable features of the SFE method is the non-toxicity of the solvents used. The carbon dioxide is the best and most efficient solvent for extracting plant compounds used in this method. In the pressurized liquid extraction (PLE) method, extraction is done using liquid solvents at high temperature and pressure, and for

this reason, it is called PLE. In this method, the extraction performance increases compared to traditional extraction methods (Richter et al., 1996). The basic principle of PLE extraction is based on the use of solvents to perform extraction at pressures and temperatures below the critical point, so that the solvent maintains its liquid state during the extraction process (Mendiola et al., 2007).

Nowadays, extraction with pressurized liquids is also used to extract polar compounds, and this method is considered as an alternative to extraction with supercritical fluid for polar compounds (Kaufmann and Christen, 2002). The most important reason for using extraction with pressurized liquids is that when using this method, high temperature and pressure during extraction not only increases the extraction performance, but also reduces the amount of solvent consumption. Extraction with subcritical water extraction (SWE) is a type of pressurized extraction in which water is used as a solvent due to its environmental suitability. Hot water under pressure is liquid water at a temperature between 100-374 °C. This temperature range is sufficient to select the expected physical and chemical properties of water and allows the extraction of many compounds without the risk of degradation (Herrero et al., 2013). The microwave extraction method is also known as a green technology because it reduces the use of organic solvent (Alupului et al., 2012). The use of enzyme extraction is also useful as an effective method to penetrate hard tissues. Adding specific enzymes such as cellulase, amylase and pectinase during extraction is essential and important (Latif & Anwar, 2009). Several factors including enzyme concentration, material particle size, solid-solvent ratio and hydrolysis time are considered as key factors of extraction (Keshavan & Hanmoungjai, 2004). The mass transfer rate in the extraction process is affected by the concentration of the desired compound and the extraction speed increases with the increase in the concentration difference of the compound in the solid bed and the solvent (Mustafa & Turner, 2011).

Considering the properties of date kernels and the potential of producing DKE, it is necessary to build a system to improve the extraction of functional compounds while maintaining the quality characteristics of the extracted compounds. Therefore, the aim of the current research is to build a date kernel extraction system for the production of instant drinks and to evaluate and determine the best operations of system for producing the high-quality product from date kernels.

MATERIALS AND METHODS

Construction of extraction chamber

The designed chamber (Figure. 1) is made of 316 steels. In the upper part of the pressure gauge, a needle was placed to observe the internal pressure of the system, and in the lower part, a cap was placed for the exit of the solution. A thermocouple connected to the display was used to observe and control the temperature of the system. A heater was used to heat the system. It should be noted that this heater is installed in a larger chamber and heat is transferred to the main chamber by means of mineral oil. The general structure of the extraction chamber includes: a) The double-walled chamber includes an internal extraction section and a section containing heated mineral oil, b) needle pressure gauge, c) thermocouples connected to inner and outer section of chamber, d) heater, e) the plate and the base of the chamber holder. In order for the solvent and the sample to reach the desired test temperature, a heater was used in a larger chamber filled with a liquid with a high boiling point (mineral oil). In this device, a 1000 w heating element was used to provide the necessary heat, which was placed at the end of the heater chamber. The temperature of the chamber was connected to the temperature indicator of the thermostat (thermocouple display) by means of a thermocouple. The reason for using a thermostat is to control the temperature of the chamber. This thermocouple was made of iron metal and copper-nickel alloys.

Also, the pressure inside the chamber was controlled by a pressure gauge. Finally, after the end of the process time, the desired solution is removed from the exit part of the chamber and dried. In the design of the device, the features of all the factors affecting the final efficiency have been taken into account.

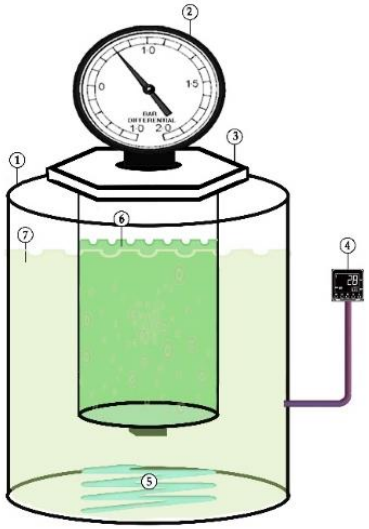

Figure 1. Schematic of the extraction chamber of date kernel compounds. 1- main double wall chamber; 2- pressure gauge; 3- upper connection of the chamber and pressure gauge; 4- thermometer; 5- heater; 6- extraction chamber; 7- Chamber containing heated mineral oil

Experimental Design

This research was conducted with the response surface method in the form of central composite design (Table 1) with Design Expert software.

Table 1. Independent variables and their applied levels for optimizing of DKE extraction from date kernels

Variables	Levels				
	1.68	1	0	-1	-1.68
Temperature (°C)	180.45	160	130	100	79.55
Time (min)	18.41	15	10	5	1.59
Liquid-to-solid ratio	5.68	5	4	3	2.32

Extraction method of DKE

A 5 g of date kernel powder was added to the extraction chamber. The water as solvent was then added to the extraction chamber at the specified liquid-to-solid ratio. Extraction process was tested at specified times and temperatures (Table 1). After the completion of the process time, the extraction chamber was cooled and its contents were removed by opening the end cap. Next, the DKE was separated from the solid residue by Buchner funnel and vacuum pump. The extract was concentrated using a vacuum rotary evaporator (RV 10, IKA, Germany) at 55 ºC. At the end, the mass of dry matter was measured to this equation:

$$\text{Extraction efficiency } (\%) = \frac{\text{Mass of the dried extract obtained from the date kernels}}{\text{Date kernal mass}} \times 100 \quad (1)$$

Total phenolic content measurement

To extract phenolic compounds, 5 ml of methanol solvent was added to 0.1 g of the homogenized DKE sample, and it was stirred for 2 hours on a shaker. Then the mixture was centrifuged at 3000 g for 10 min. The supernatant was used to measure the TPC. The 100 µL of the extract was mixed with 0.75 ml Folin–Ciocalteu reagent (diluted with distilled water at a ratio of 1:10). Then it was kept at room temperature for 5 minutes. Finally, 0.75 ml of sodium bicarbonate 7.5% w/v was added to the mixture and kept for 10 minutes at room temperature in a dark place. The absorbance of the samples was measured at a wavelength of 725 nm using a Unico 2802 UV/VIS spectrophotometer. Gallic acid was used to prepare the standard curve (Platat et al., 2015).

Measurement of antioxidant activity

The antioxidant activities of the DKE were studied through the evaluation of the free radical-scavenging effect on the 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical with some modification (Platat et al., 2015). The 600 µL of 0.2 mM DPPH reagent in methanol were mixed with 600 µL of diluted extract at a ratio of 1:50. The desired mixture was placed in a dark place for 15 min. Absorbance was measured at 520 nm with a Unico 2802 UV/VIS spectrophotometer.

Measurement of melanoidins

Melanoidins were estimated by means of browning intensity of the extracted samples. Browning intensity was measured at 360 and 420 nm wavelengths using a Unico 2802 UV/VIS spectrophotometer (Plaza et al., 2013).

Sensory evaluation

Sensory tests with semi-trained 12 panelists were performed using a hedonic scale of 1 (dislike extremely) to 9 (like extremely) for color and appearance, taste, aroma, and overall acceptance. Scores from 5 to 9 were considered acceptable. The panelists used water and unsalted crackers as palate cleansers between tasting the samples.

RESULTS AND DISCUSSION

According to the results, the content of protein, fat, ash, carbohydrate and moisture of date kernel powder was 6.26, 11.9, 0.7, 77.74 and 3.4% respectively. The resulting DKE samples were prepared from date kernel powder. This extract was produced using the developed system, in a completely hygienic manner, without any additives, in suitable conditions at the levels of the experimental design. Then, the quality characteristics of DKE was were evaluated by using the central composite design method. Table 2 shows the results and data obtained in the experiments. In the following, the results of the statistical analysis are presented and discussed.

Table 2. Central composite design of samples based on RSM model for responses of DKE

Run	Temp. (°C)	Time (min)	Liquid-solid ratio	Extraction yield (%)	TSS (°Brix)	TPC (mg/g)	Antioxidant activity (%)	Melanoidins (Abs.)
1	160.00	15.00	3.00	21.01	11.65	15.72	95.80	0.27
2	160.00	5.00	3.00	20.84	11.60	21.72	78.30	0.26
3	130.00	10.00	4.00	18.73	11.25	25.01	72.00	0.22
4	100.00	15.00	3.00	13.12	10.80	19.12	49.95	0.20
5	180.45	10.00	4.00	24.13	11.40	13.42	97.20	0.25
6	160.00	15.00	5.00	20.59	11.20	15.00	96.50	0.26
7	100.00	5.00	3.00	12.47	10.50	14.11	34.90	0.19
8	130.00	10.00	4.00	18.49	11.10	24.97	71.00	0.22
9	100.00	5.00	5.00	12.41	9.65	22.61	46.25	0.20
10	130.00	18.41	4.00	17.31	11.35	23.00	81.10	0.28
11	79.55	10.00	4.00	9.46	8.85	10.11	30.10	0.15
12	160.00	5.00	5.00	20.58	10.90	16.12	82.50	0.26
13	130.00	10.00	4.00	17.99	10.85	25.62	67.10	0.23
14	100.00	15.00	5.00	14.78	9.54	20.08	47.15	0.22
15	130.00	10.00	5.68	17.84	10.10	23.04	51.70	0.24
16	130.00	1.59	4.00	18.88	10.40	22.94	58.00	0.22
17	130.00	10.00	2.31	18.31	11.45	22.04	56.25	0.23

Extraction efficiency

The analysis of variance of the different independent factors (temperature and time of processing and liquid-to-solid ration) on the extraction efficiency of DKE form date kernels are given in Table 3.

Table 3. Results of the analysis of variance of data on the extraction efficiency of DKE obtained from date kernels

Source	Sum of squares	df	Mean of squares	F Value	p-value Prob > F
Model*	259.83	9	28.87	293.38	<0.0001
A: Temperature*	238.67	1	238.67	2425.31	<0.0001
B: Time*	10.79	1	10.79	109.64	<0.0001
C: Liquid-solid ratio*	0.72	1	0.72	7.30	0.0306
AB	0.34	1	0.34	3.42	0.1070
AC*	1.17	1	1.17	11.89	0.0107
BC*	2.25	1	2.25	22.84	0.0020
A^2*	4.86	1	4.86	49.43	0.0002
B^2	5.569E-003	1	5.569E-003	0.057	0.8188
C^2	1.65	1	1.65	16.79	0.0046
Residual	0.69	7	0.098		
Pure error	0.60	2	0.045		
Cor Total	260.52	16			

*Significant at the 5% level

The results of variance analysis of the data showed that the effect of all three factors of temperature, time and ratio of liquid-to-solid on the amount of DKE was significant (Table 3). As shown in Figure 3a, the extraction efficiency increased with increasing temperature. The yield changes are according to equation (2):

$$\text{Extraction yield} = 18.74 + 4.18A + 0.89B + 0.362C - 0.38AC - 0.53BC - 0.66A^2 - 0.38C^2 \quad (2)$$

where, A: temperature, B: time, C: liquid-to-solid ratio, A^2: square of temperature, C^2: square of liquid-to-solid ratio, AC: interaction of temperature and liquid-to-solid ratio, and BC: interaction of time and liquid-to-solid ratio. The fitted model was significant at 5% level and R^2 was equal to 0.95. According to the research conducted on almond oil by Zhang et al. (2009), the effect of all variables was significant at the 95%; Also, the interaction effect of the variables was not significant (Zhang et al., 2009), which is consistent with the results of the present study. Also, in the research conducted on date kernel oil by Özkal et al. (2005) the linear effect of the parameters and the double interaction effect of the parameters were significant at the 5%. Comparison of the average data showed that the maximum amount of the extracted substance is related to the temperature of 124.49 ºC, the time of 8.49 min and the ratio of liquid-to-solid of 4.48. The results of the tests are shown in (Figure 2).

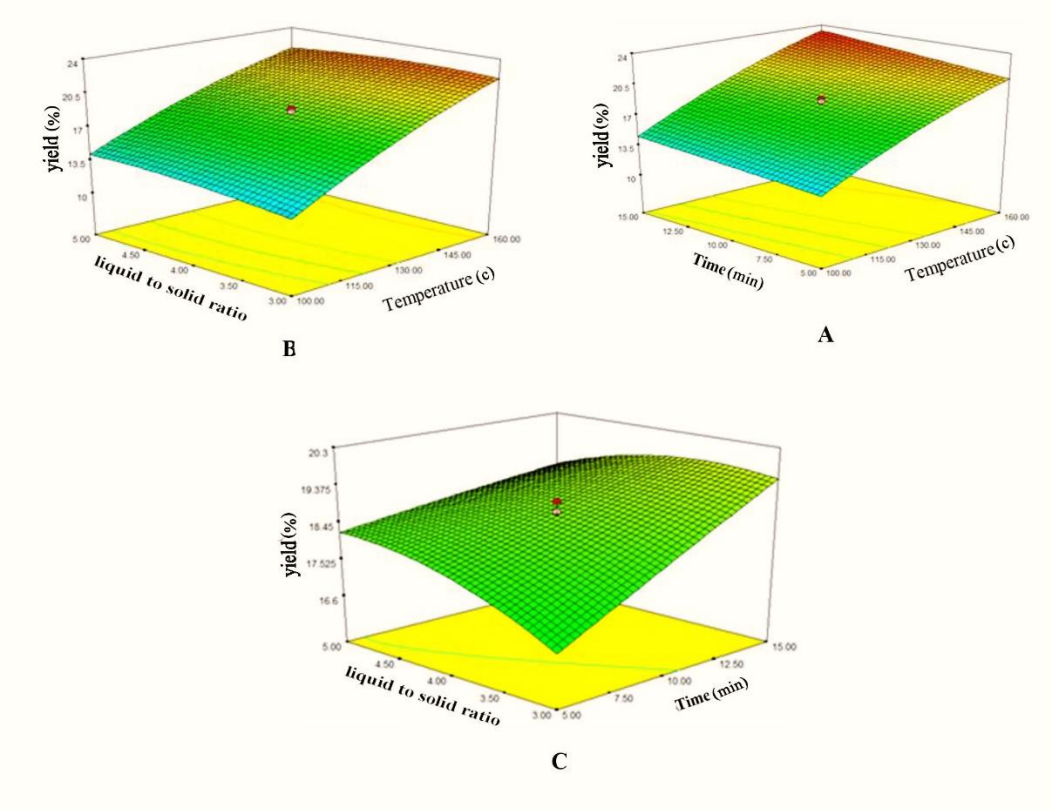

Figure 2. Effect of processing time and temperature and liquid-to-solid ratio on the yield of date kernel

Antioxidant activity

The results of variance analysis of the data showed that the effect of all three factors of temperature, time and liquid-to-solid ratio on the antioxidant activity of the produced extract was significant (Table 4). Also, the squared effects of liquid-to-solid ratio on the antioxidant property of the produced extract were significant at the 5% probability level. As shown in Figure 3c, with the increase of time, the antioxidant activity increased non-linearly.

Table 4. Results of the analysis of variance of data on the antioxidant activity of DKE obtained from date kernels

Source	Sum of squares	df	Mean of squares	F Value	p-value Prob > F
Model*	6977.03	9	775.23	42.03	<0.0001
A: Temperature*	6045.24	1	6045.24	327.74	<0.0001
B: Time*	527.17	1	527.17	28.58	0.0011
C: Liquid-solid ratio*	133.08	1	133.08	7.22	0.0313
AB	3.65	1	3.65	0.20	0.6698
AC	9.54	1	9.54	0.52	0.4954
BC	30.27	1	30.27	1.64	0.2410
A^2	4.57	1	4.57	0.25	0.6338
B^2	3.36	1	3.36	0.18	0.6825
C^2*	217.94	1	217.94	11.82	0.0109
Residual	129.12	7	18.45		
Pure error	126.47	2	1.32		
Cor Total	7106.15	16			

*Significant at the 5% level

The changes in the antioxidant activates are according to equation (3):

$$\text{Antioxidant activity} = 70.72 + 21.04A + 6.21B + 3.21C - 4.40C^2 \quad (3)$$

where, A: temperature, B: time, C: liquid-to-solid ratio, C^2: the square of the ratio of liquid-to-solid. The fitted model for production DKE is significant at the 5% level, and R^2 is equal to 0.98. According to the research conducted on the phenolic compounds of instant coffee by Mossato et al. (2011) the model and the effects of linear variables, which include concentration and ratio of liquid-to-solid, were reported to be significant at the 5% level. Also, the square effect of liquid-to-solid ratio was significant. It should be mentioned that in this research the interaction effect of the variables was also significant (Mussatto et al. 2011).

Comparison of the average data showed that the best antioxidant activity corresponds to the temperature of 124.49 ºC, the time of 8.48 min and the ratio of liquid-to-solid of 4.48 (Figure. 3).

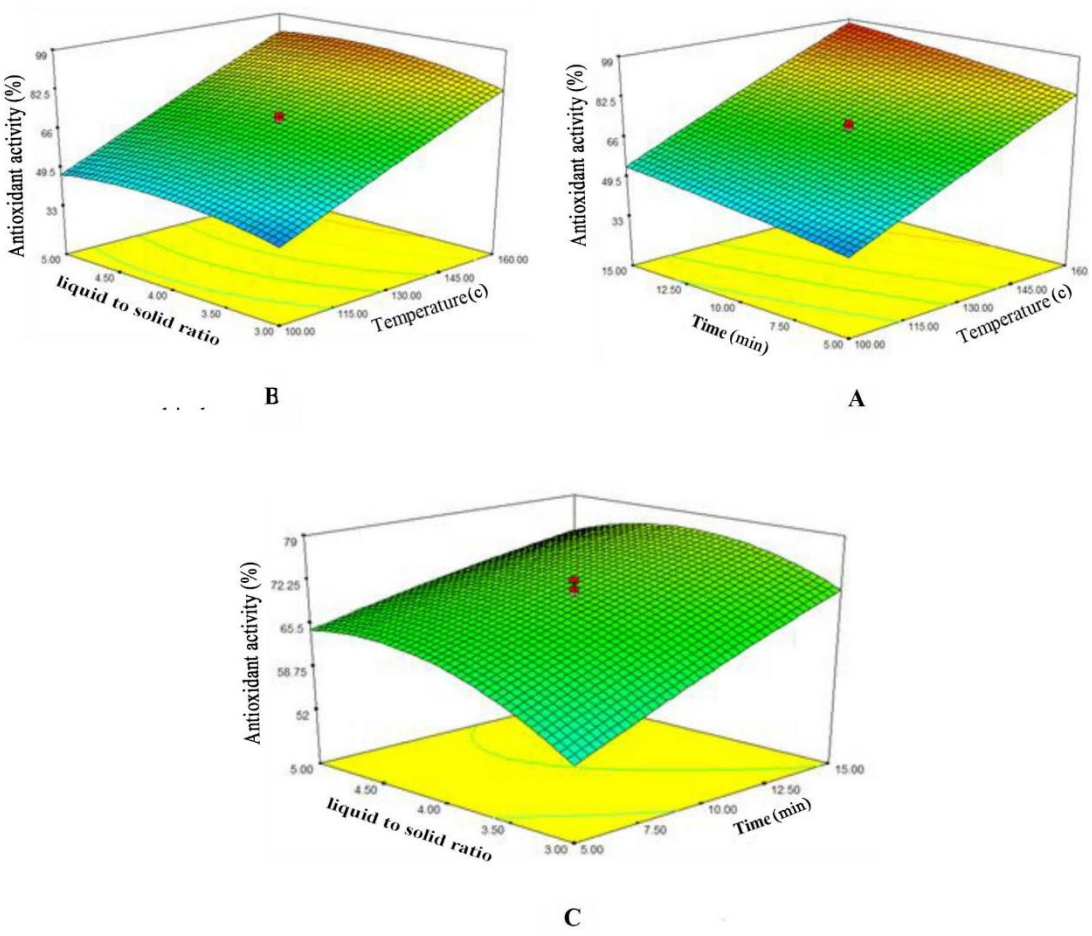

Figure 3. Effect of processing time and temperature and liquid-to-solid ratio on the antioxidant activity of DKE

Total soluble solids

The analysis of variance of the different independent factors (temperature and time of processing and liquid-to-solid ration) on the TSS of DKE are given in Table 5.

Table 5. Results of the analysis of variance of data on the TSS of DKE obtained from date kernels

Source	Sum of squares	df	Mean of squares	F Value	p-value Prob > F
Model*	4.56	9	0.51	10.53	0.0026
A: Temperature*	2.20	1	2.20	45.65	0.0003
B: Time*	0.69	1	0.69	14.34	0.0068
C: Liquid-solid ratio*	1.06	1	1.06	22.09	0.0022
AB	0.088	1	0.088	1.83	0.2179
AC	0.072	1	0.072	1.50	0.2603
BC	0.088	1	0.088	1.83	0.2179
A^2*	0.27	1	0.27	5.61	0.0497
B^2	0.086	1	0.086	1.80	0.2221
C^2	0.19	1	0.19	3.96	0.0870
Residual	0.34	7	0.048		
Pure error	0.29	2	0.026		
Cor Total	49.4	16			

*Significant at the 5% level

The results of variance analysis of the data showed that the effect of all three factors of temperature, time and liquid-to-solid ratio on the dissolved solids of the produced extract is significant (Table 5). Also, the squared effect of temperature on the dissolved solids in the DKE was significant at the 5% probability level. As shown in Figure. 4, with increasing temperature, the amount of TSS increased non-linearly.

The changes of TSS are according to equation (4):

$$TSS=11.24 + 0.40A + 0.22B – 0.28C – 0.15A^2 \quad (4)$$

where, A: temperature, B: time, C: liquid-to-solid ratio, A^2: the square of temperature. The fitted model for the production extract is significant at the 5% level, and R^2 is equal to 0.93. Comparison of average data showed that the best point of dissolved solids is related to temperature 131.81 ºC, time 7.15 min and ratio of liquid-to-solid 3.49. The TSS results are shown in Figure 4.

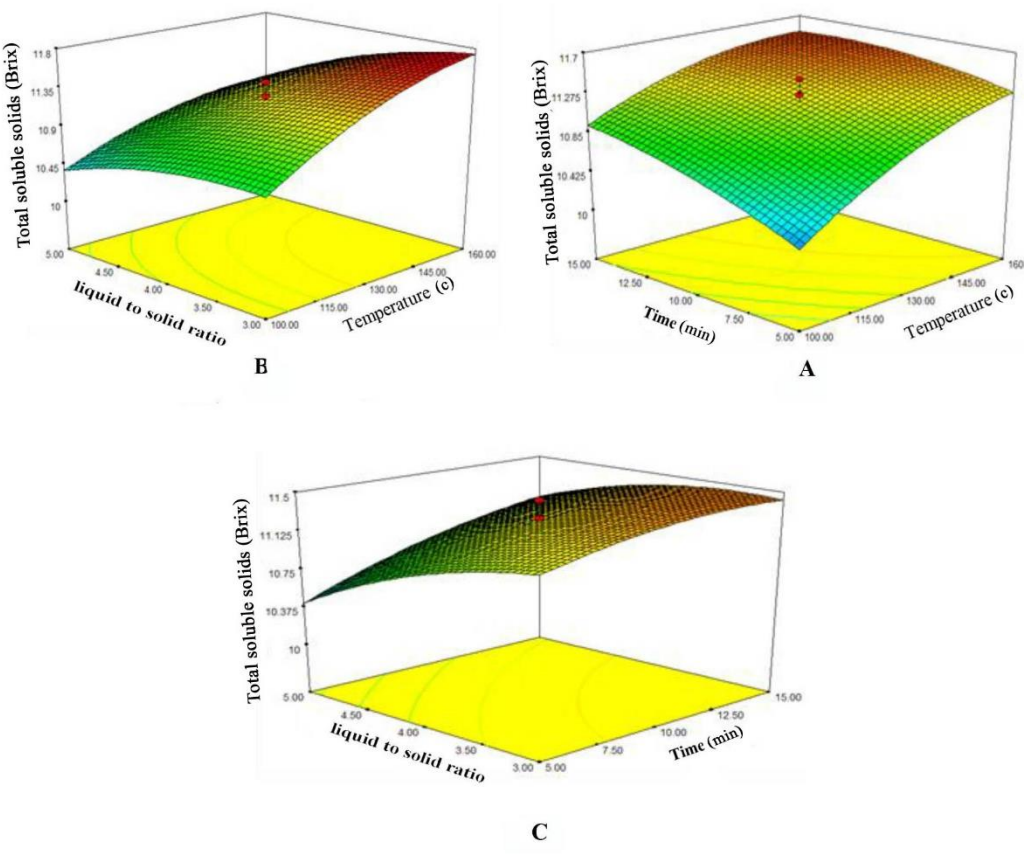

Figure 4. Effect of processing time and temperature and liquid-to-solid ratio on the total soluble solids (TSS) of DKE

Total phenolic content

The analysis of variance of the different independent factors (temperature and time of processing and liquid-to-solid ration) on the TPC of DKE are given in Table 6.

Table 6. Results of the analysis of variance of data on the TPC of DKE obtained from date kernels

Source	Sum of squares	df	Mean of squares	F Value	p-value Prob > F
Model*	169.08	9	18.79	11.97	0.0018
A: Temperature*	58.43	1	57.43	36.61	0.0005
B: Time*	16.44	1	16.44	10.48	0.0143
C: Liquid-solid ratio*	22.22	1	22.22	14.16	0.0070
AB	3.09	1	3.09	1.97	0.2033
AC	0.077	1	0.077	0.049	0.8313
BC*	30.02	1	30.02	19.13	0.0033
A^2*	32.83	1	32.83	20.92	0.0026
B^2*	17.03	1	17.03	10.86	0.0132
C^2	8.41	1	8.41	5.36	0.0538
Residual	10.98	7	1.57		
Pure error	10.98	2	0.002		
Cor Total	6.180	16			

*Significant at the 5% level

The results of variance analysis of the data showed that the effect of all three factors of temperature, time and liquid-to-solid ratio on the amount of phenolic compounds in the produced extract was significant (Table 6). Also, the mutual effects of liquid-to-solid ratio-time and

the square of temperature and the square of time on the amount of phenolic compounds of the produced extract were significant at the 5% probability level. As shown in Figure 4c, with the increase of liquid-to-solid ratio, the amount of TPC increased non-linearly.

The changes of TPC are according to equation (5):

$$TPC = 25.04 + 2.05A + 1.10B + 1.28C - 1.94BC - 1.71A^2 - 1.23B^2 \quad (5)$$

where, A: temperature, B: time, C: liquid-to-solid ratio, A^2: the square of temperature, B^2: the square of time, BC: the interaction of time with the liquid-to-solid ratio.

The fitted model for the production extract is significant at the 5% level, and R^2 is equal to 0.93. In the research conducted on TPC of instant coffee by Mussatto et al. (2011), only the effect of one of the linear variables was reported to be significant at the 5% level, and the effect of the other linear variable like concentration was not significant. Also, the effect of the square of the concentration was significant, but the square of the ratio of liquid-to-solid was not significant. It should be noted that the interaction effect of the variables was also significant) Mussatto et al. 2011).

Comparison of average data showed that the best point of TPC is related to temperature 152.52 ºC, time 7.47 min and liquid-to-solid ratio 4.04. The results of the tests are shown in (Figure. 5).

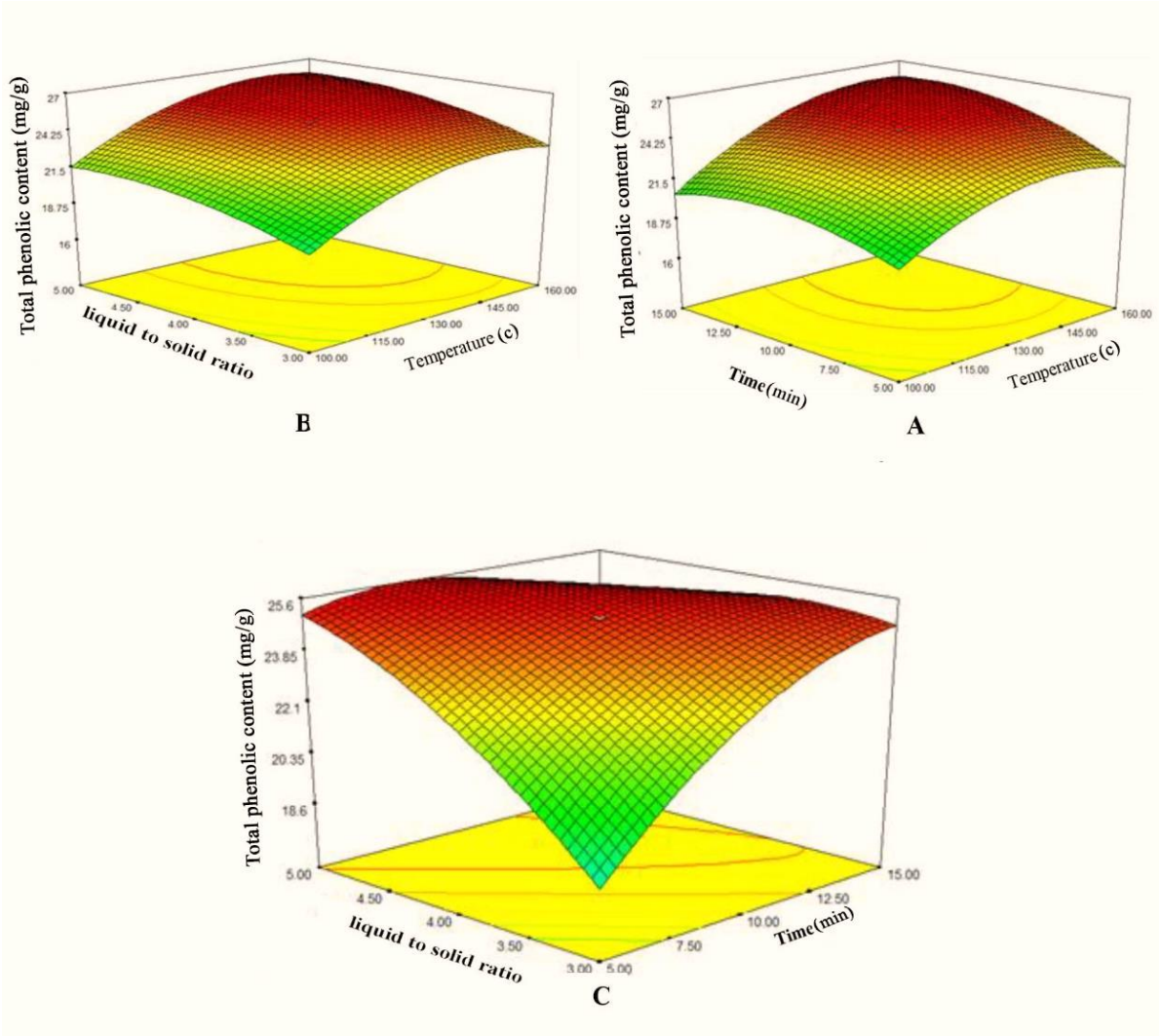

Figure 5. Effect of processing time and temperature and liquid-to-solid ratio on the TPC of DKE

Melanoidins

The analysis of variance of the different independent factors (temperature and time of processing and liquid-to-solid ration) on the melanoidins of DKE was recorded (Table 7).

Table 7. Results of the analysis of variance of data on the melanoidin of DKE obtained from date kernels

Source	Sum of squares	df	Mean of squares	F Value	p-value Prob > F
Model*	0.01585	9	0.00176	15.39	0.0008
A: Temperature*	0.00816	1	0.00816	71.31	<0.0001
B: Time*	0.00136	1	0.00136	11.91	0.0107
C: Liquid-solid ratio*	0.00070	1	0.00070	6.18	0.0419
AB	0.00010	1	0.00010	0.92	0.3704
AC	0.00030	1	0.00030	2.65	0.1474
BC	0.00001	1	0.00001	0.094	0.7678
A^2*	0.00150	1	0.00150	13.18	0.0084
B^2*	0.00212	1	0.00212	18.57	0.0035
C^2	0.00007	1	0.00007	0.68	0.4358
Residual	0.00080	7	0.00011		
Pure error	0.00075	2	0.00002		
Cor Total	0.01665	16			

*Significant at the 5% level

The results of variance analysis of the data showed that the effect of all three factors of temperature, time and liquid-to-solid ratio on the amount of melanoidin compounds in the produced extract was significant (Table 7). Also, the effects of the square of temperature and the square of time on the melanoidins of the produced extract were significant.

The changes of melanoidins are according to equation (6):

$$\text{Melanoidin} = 0.23 + 0.024A + 0.009B + 0.007C - 0.012A^2 + 0.014B^2 \quad (6)$$

where, A: temperature, B: time, C: liquid-to-solid ratio, A^2: the square of temperature, B^2: the square of time. The fitted model for the production extract is significant at the 5% level, and its R^2 is equal to 0.95. In the research conducted on the turbidity of banana juice by Lee et al. (2006) the linear effect of concentration and time variable was significant at 5%, and the linear effect of temperature was also reported to be significant. Among the interactions, only the concentration-time interaction was significant at the 5% level (Lee et al. 2006). Comparison of the average data showed that the best point of melanoidins corresponds to the temperature of 152.52 ºC, the time of 7.47 min and the ratio of liquid-to-solid of 4.08. The results of the tests are shown in (Figure. 6).

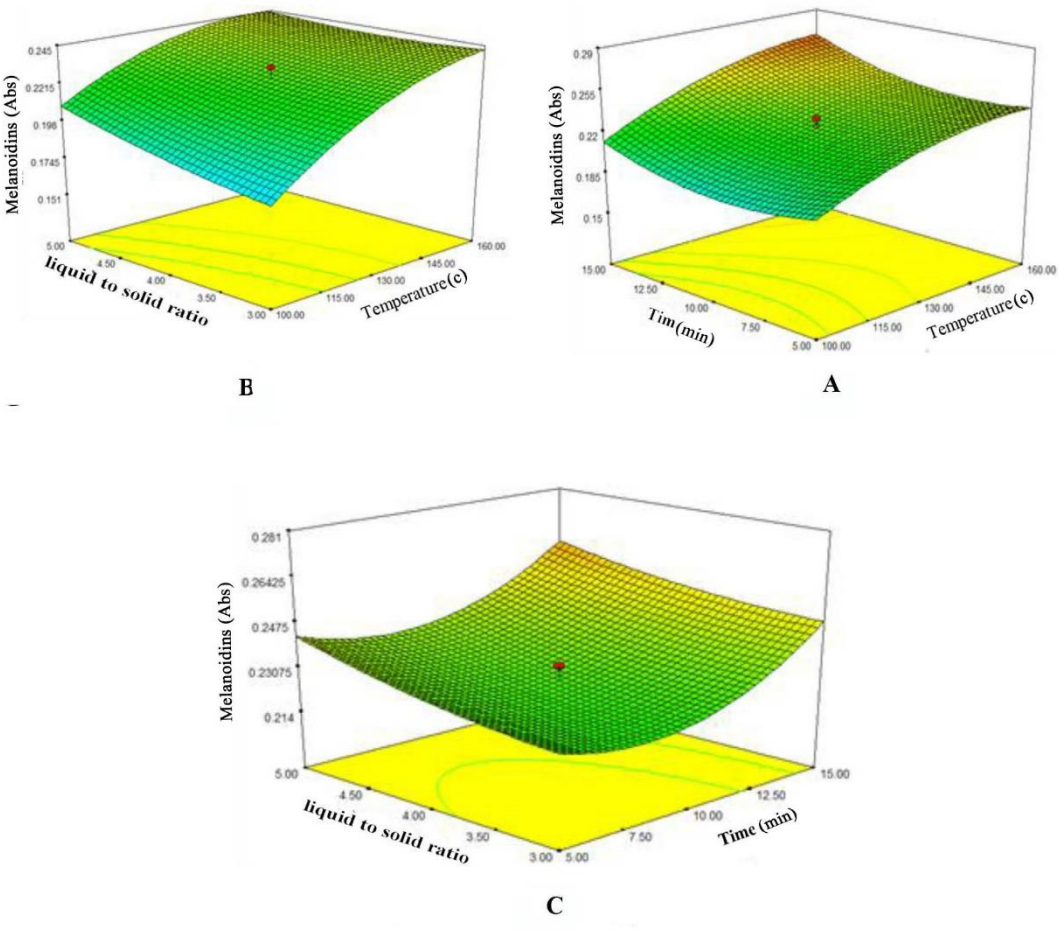

Fig 6. Effect of processing time and temperature and liquid-to-solid ratio on the melanoidin of DKE

Sensory properties

The sample of DKE under optimal conditions was compared and evaluated with a commercial date powder (CDP) and an instant coffee sample in terms of aroma, taste, color and appearance, and overall acceptance (Table 8). By comparing the aroma, it was observed that DKE had a high favorability compared to CDP, while this favorability was lower compared to instant coffee. The taste scores showed that the level of satisfaction with DKE was higher than with CDP, while this satisfaction was lower compared to instant coffee. By examining the color and appearance scores, the satisfaction level of DKE was significantly higher than CDP, but compared to instant coffee, there was no significant difference. Also, the overall acceptance of the panelists showed that the level of satisfaction of DKE was higher than that of CDP, but this level was not significantly different compared to instant coffee.

Table 8. Sensory evolution of DKE compared to commercial samples

Sensory attributes	Date kernel extract	Commercial date kernel powder	Instant coffee
Aroma	7.60±0.5^{a}	4.52±0.46^{b}	7.48±0.81^{a}
Taste	7.18±0.56^{a}	3.80±1.27^{b}	6.44±0.69^{a}
Color	7.68±0.48^{a}	5.07±0.86^{b}	7.57±0.55^{a}
Overall acceptance	7.65±0.39^{a}	5.85±0.81^{b}	7.08±0.62^{ab}

* The data marked with same letter in row have no significant difference at the 5% level.

CONCLUSION

Date kernel is one of the agricultural wastes that is obtained from various industrial processes in date processing industries such as date syrup industry, date sugar, citric acid production and confectionery. This side product has dietary fibers, fat and protein. In the present research, first, a high-temperature extraction device was designed, then the efficiency of the system to extract the desired compounds of date kernels for possible use as instant powder was investigated, and then the quality characteristics of the dried extract, including TSS, TPC, antioxidant activity, and melanoidins were evaluated. The obtained results showed that the factors of temperature and time of processing and ratio of liquid-to-solid have a direct effect on the extraction efficiency and the quality characteristics of the final product.

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